# The US Navy's Coupled Atmosphere-Ocean-Wave-Sea Ice System

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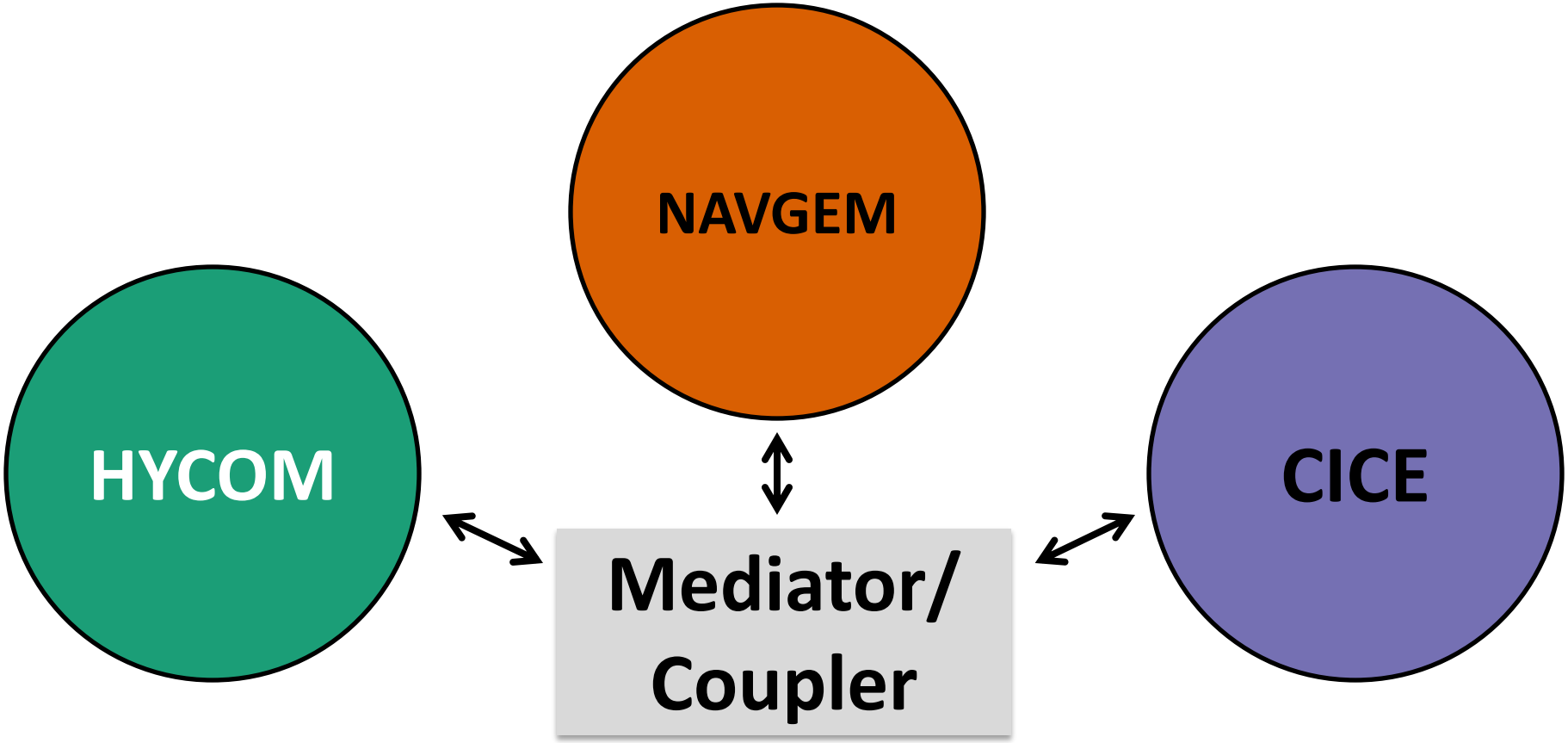
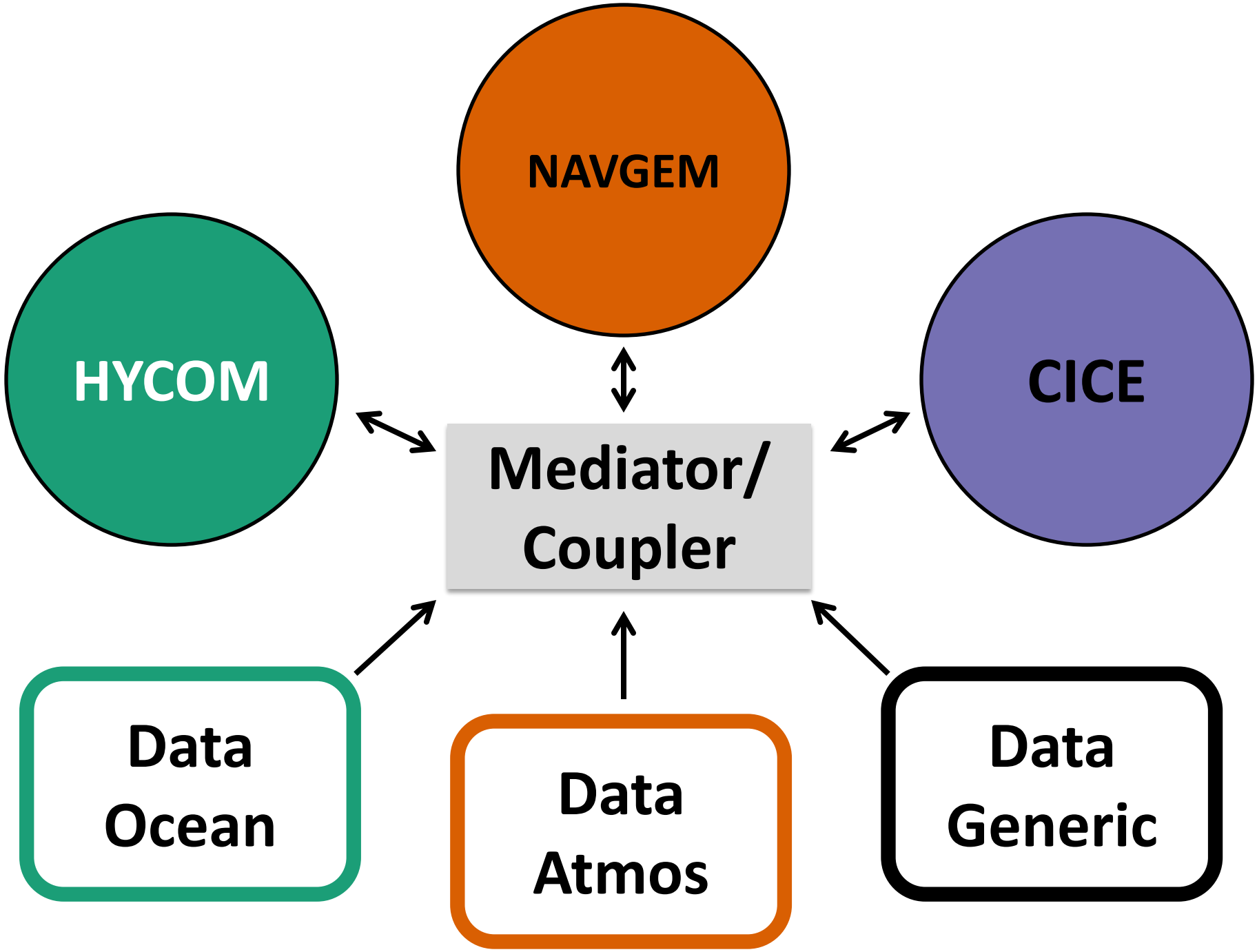
# Descriptions of Models

| Model | Atmosphere | Ocean | Sea Ice |
|---|---|---|---|
| Name | **NAVGEM** | **HYCOM** | **CICE** |
| Agency | **DoD** | **DoD** | **DOE** |
| Current Resolution | **T359L50 (~37 km 50 levels)** | **GLBb0.08 (~9 km 41 layers)** | **GLBb0.08 (~9 km 4 layers)** |

**Mediator/Coupler**: Earth System Modeling Framework (ESMF)/National Unified Operational Prediction Capability (NUOPC)

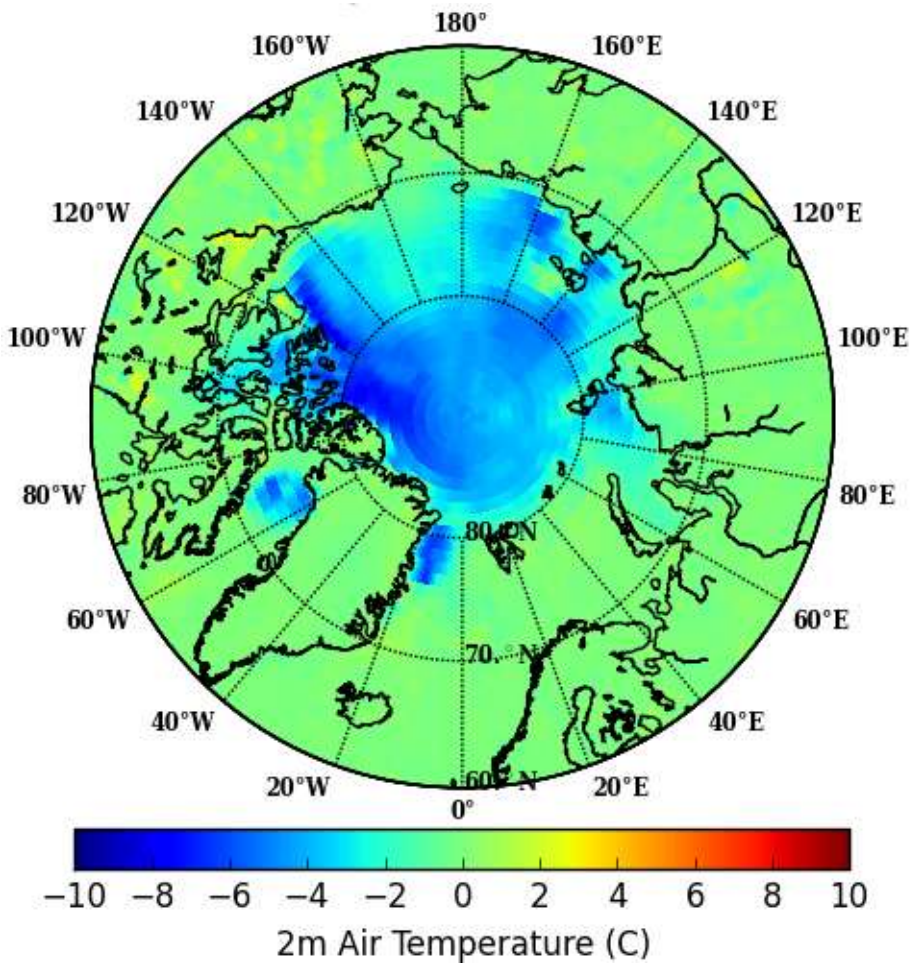
# System Design

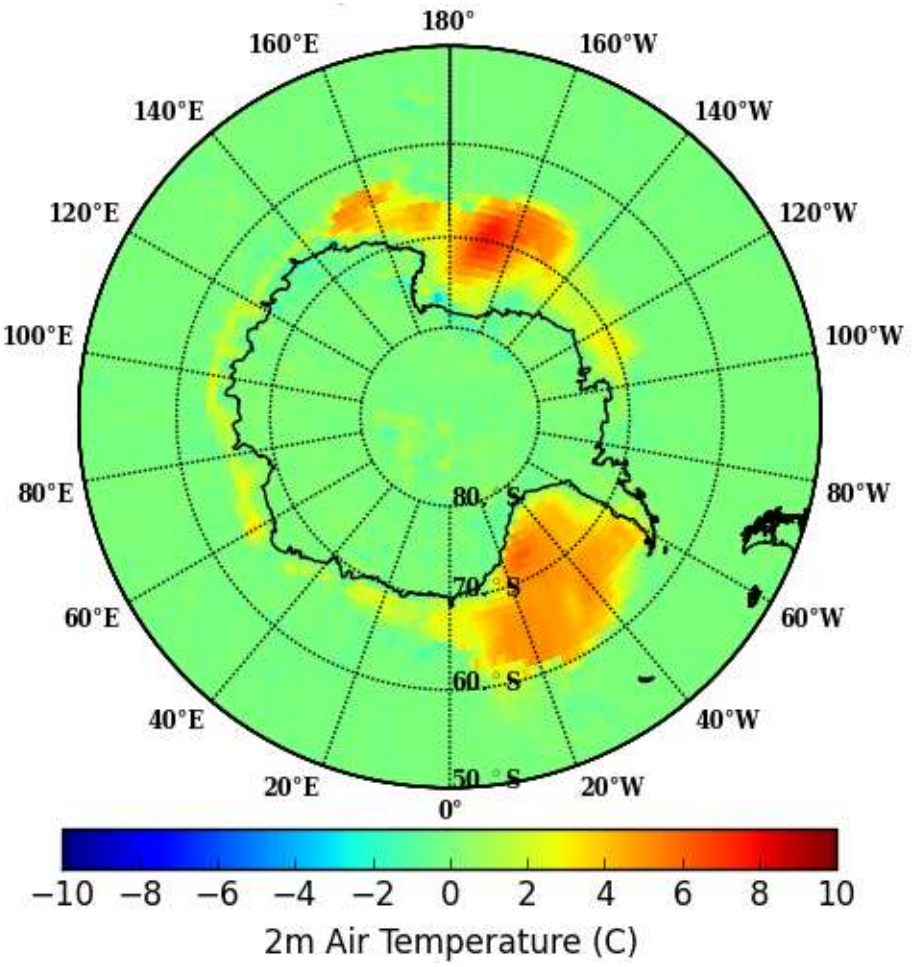

NAVGEM
HYCOM
CICE
Mediator/
Coupler


NAVGEM
HYCOM
CICE
Mediator/
Coupler
Data
Ocean
Data
Atmos
Data
Generic

# Interactions with Atmospheric DA

## Mean analysis difference of 2m Temperature between NAVGEM w/CICE5 and NAVGEM control for May2014



# Products & Skill Assessment

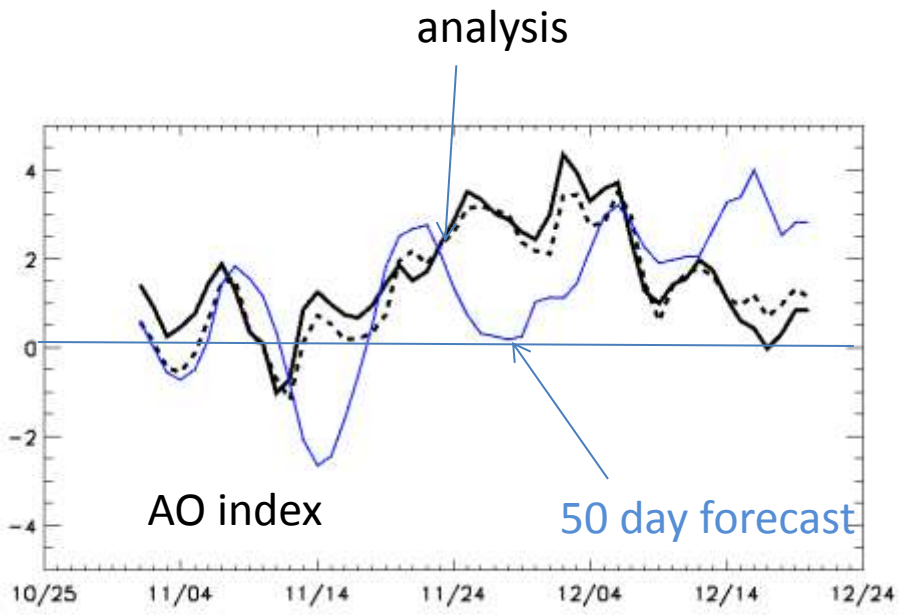
Sub-seasonal diagnostics for the ESPC system are under development

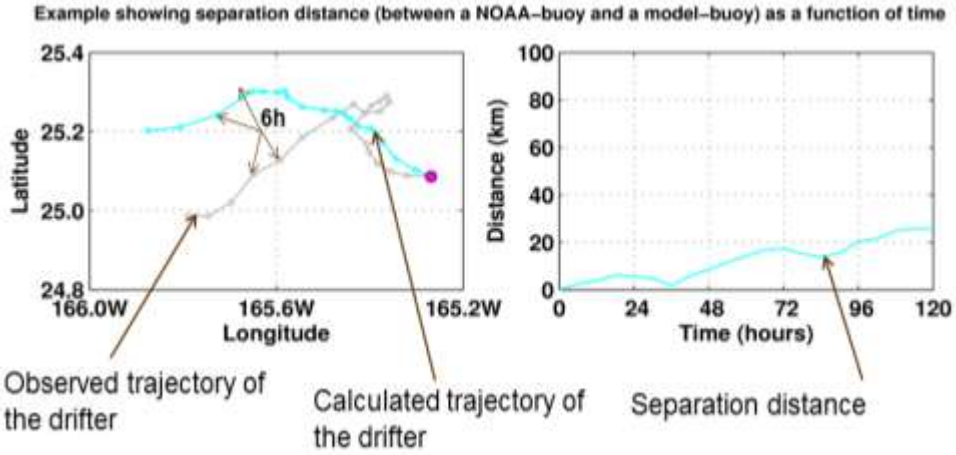
**Existing diagnostics**:

- RMMI MJO index
- AO/AAO indices
- Equatorial and regional precipitation diagnostics
- SST bias/error
- Mixed layer characteristics
- Surface currents
- Sea Ice percentage/volume

**Planned:**

- NAO
- Monsoons
- Tropical cyclogenesis/tropical depressions tracking
- Extreme events.



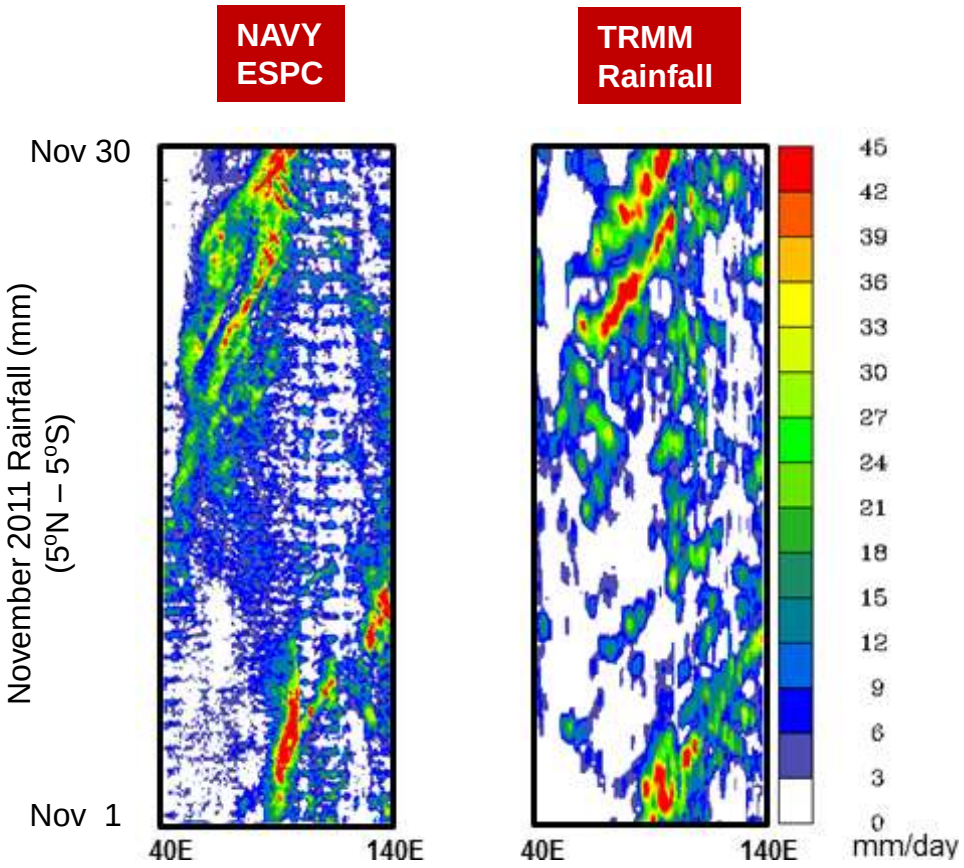
# Focus on Madden-Julian Oscillation

**MJO Rainfall Prediction - Integrations from November 1, 2011**

Considerable progress has been made in representing the Nov. 2011 DYNAMO period MJO events.

Propagation across the Maritime Continent remains a challenge.

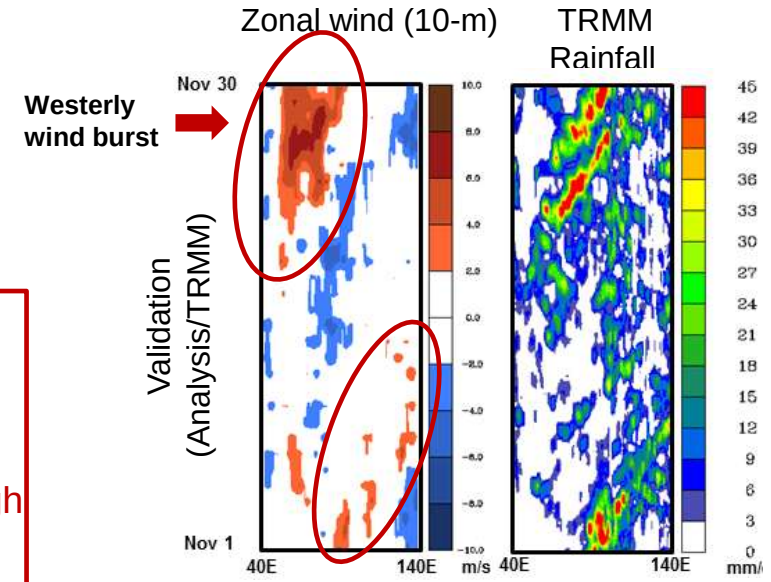
Preparations for ensemble tests are underway.



# NAVY ESPC NAVGEM-HYCOM-CICE System

## MJO / Ocean Interactions

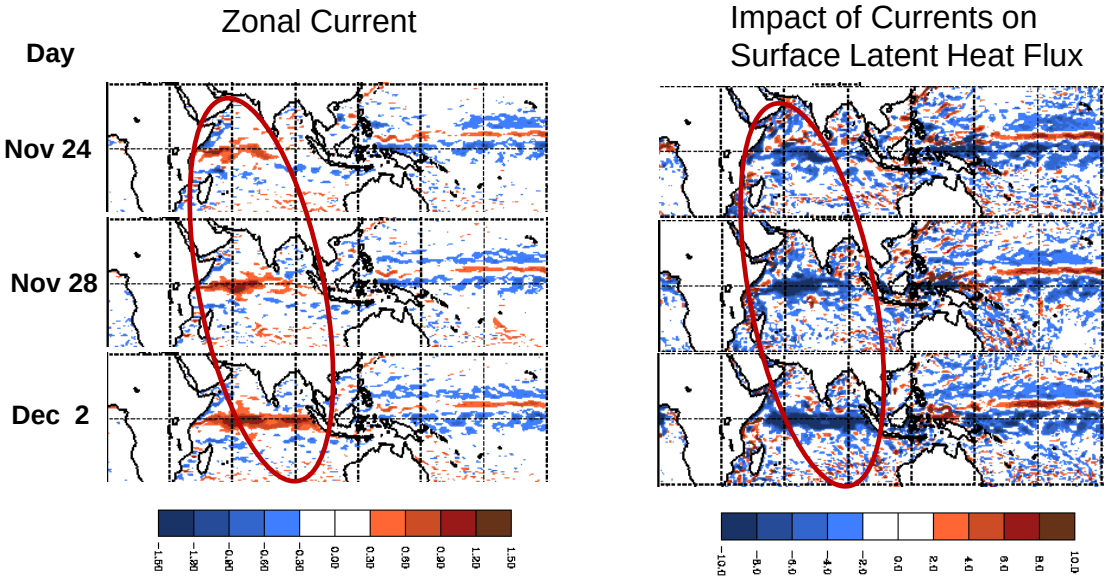
Prediction of ENSO (El Nino – Southern Oscillation) events in the coupled system will require a realistic ocean response to westerly wind bursts associated with the MJO.



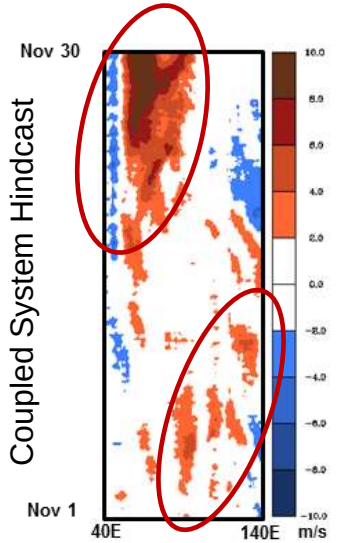

**Simulated zonal current development associated with the westerly wind burst during the second MJO episode during DYNAMO (left). Diagnosed impact of currents on surface latent-heat flux (right).**

Ocean Response to MJO

Feedbacks to Atmosphere Through Current effect on Surface Fluxes



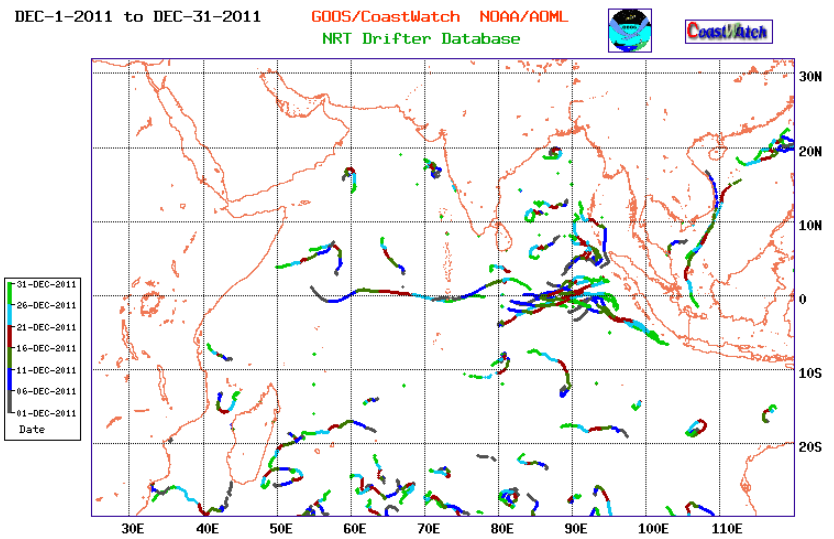

**Westerly wind burst in ESPC coupled system hindcast – too strong and overly extensive.**



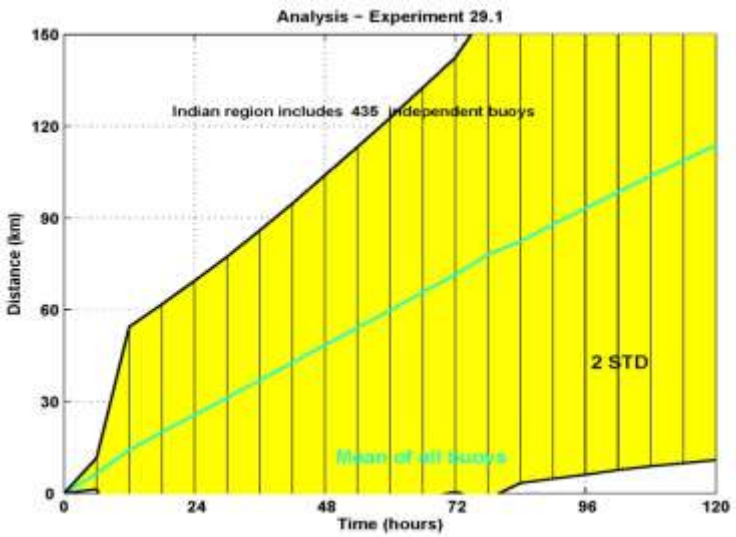
# NAVY ESPC NAVGEM-HYCOM-CICE System

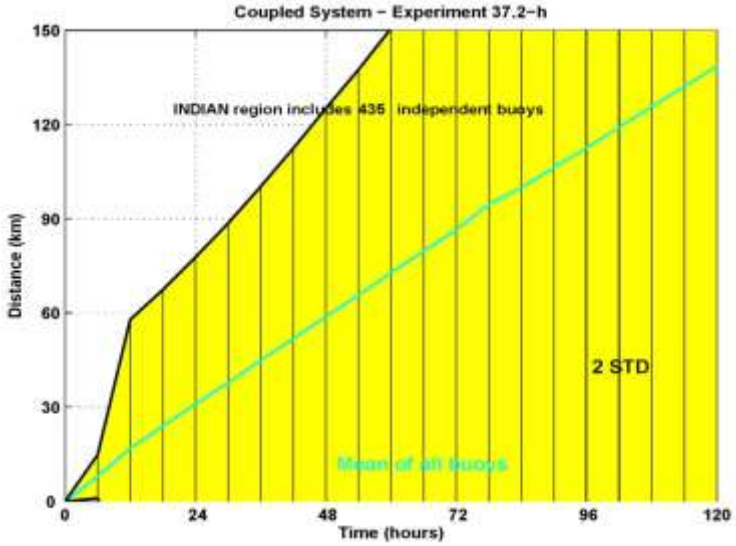
## Ocean Validation in 50-day Coupled Hindcast

- Separation of predicted surface drifter trajectories are compared for the last 30 days of the hindcast
- While the sample size is small, the hindcast error is only slightly larger than a standalone ocean-only analysis.
- Drifter trajectories are not assimilated in the analysis




Drifters deployed during DYNAMO period



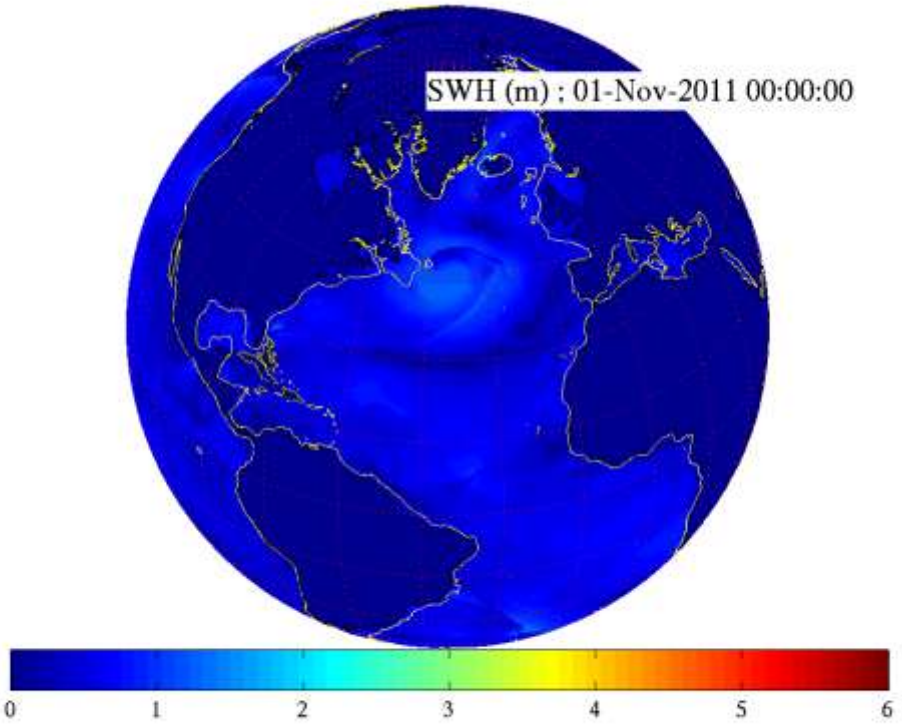
# NAVY ESPC NAVGEM-HYCOM-CICE System

## Demonstration of Wave Watch 3 on ESPC 1/4° Tripole Grid

- Wave Watch 3 has been implemented on the ESPC tri-pole grid

- Data models are used for the ocean and atmosphere, importing
  1) ocean sea level
  2) 10 m wind speeds (vector)
  3) surface currents (vector)
  4) ice concentration

- The currents are doing the following to the wave model :
  1) shifting energy in frequency space
  2) changing effective wind stress
  3) refracting wave energy




The short animation shows the spinup of waves from strong storms in the North Atlantic and North Pacific (regions where curvature of the tri-pole grid occurs) and intensification of waves by the Gulf Stream

# Requirements for Future Development

- Weakly coupled DA
  - Scripting for Atmospheric DA is set up
  - Need scripting for Ocean/Ice DA
  - Need scripting to combined Atmospheric and Ocean/Ice DA
- Ensemble Hindcasting
  - Time Lagged currently possible, but not routinely used
  - Exploring Possible more complex Ensemble Options (e.g., perturbed obs.)
- Tighter Coupling Between NAVGEM and CICE
- Diagnostics!

# Readiness For Research

## Current Status

1) The NAVY ESPC System is being used for 30 – 50 day hindcasts in research mode in preparation for operational implementation in 2018.

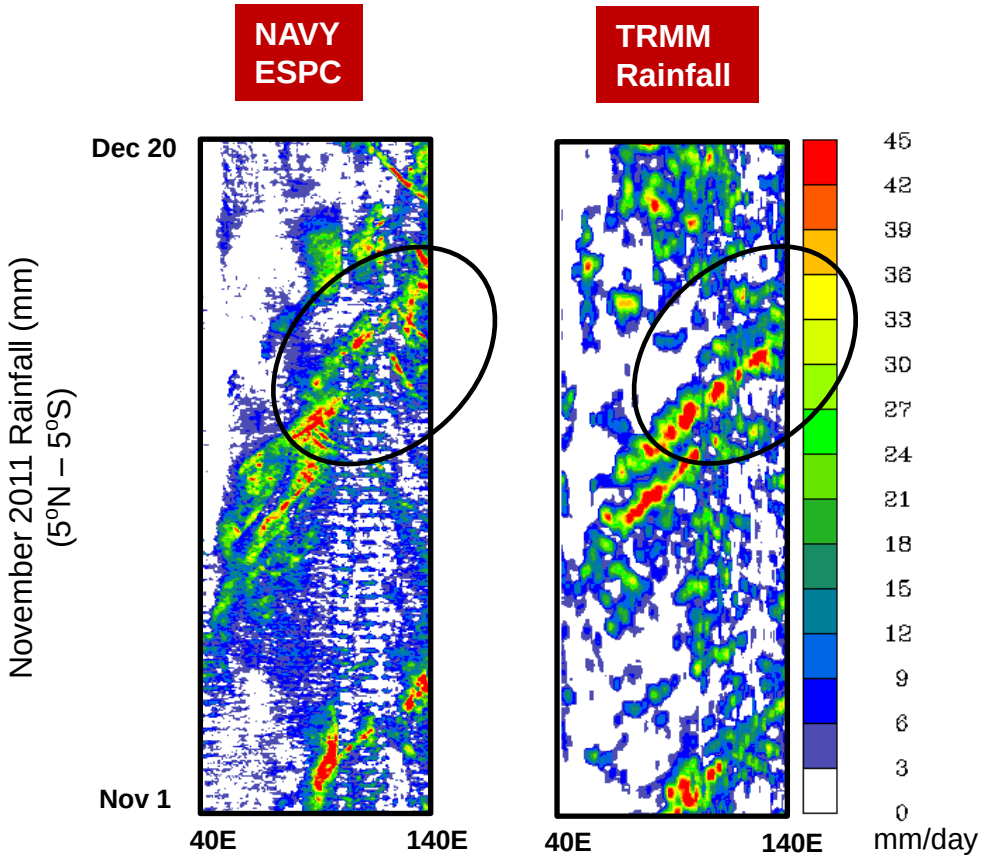
2) Initial states currently come from component model analyses. A coupled system data assimilation capability is not yet in place.

3) Combined ONR/NRL funding, coupled system hindcasts and participation with an early version of NAVGEM in the joint MJO Task force/YOTC/GEWEX international model intercomparison project, "Vertical Structure and Diabatic Processes of the MJO", have contributed to considerable progress towards improving the representation of the MJO in the system.

4) Arctic sea ice summer melt hindcasts for 2014 are within the range of dynamical models participating in the Sea Ice Prediction Network (SIPN).

# EXTRA SLIDES

# MJO Rainfall Prediction - 50-Day Integration from November 1, 2011




Propagation across the Maritime Continent Remains a Challenge